



# High-Performance Windows Market Transformation Plan

Center for Energy and Environment

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# INTRODUCTION

## Minnesota Efficient Technology Accelerator

The Minnesota Efficient Technology Accelerator (ETA) is a statewide market transformation program that accelerates deployment and reduces the cost of emerging and innovative efficient technologies, bringing lower energy bills and environmental benefits to Minnesotans. The ETA is a partnership funded by the state's investor-owned utilities (IOUs), administered by the Minnesota Department of Commerce, Division of Energy Resources (DER), and implemented by Center for Energy and Environment (CEE).<sup>1</sup>

The ETA program has set four overarching goals:

- Create a strategic process to accelerate market deployment of key technologies.
- Employ effective strategies to leverage market forces.
- Become a hub for collaboration among stakeholders.
- Achieve cost-effective energy savings and other benefits for utilities and Minnesotans.

The ETA program develops individual market transformation initiatives for a handful of targeted technologies and approaches, often starting at an early stage of development. The ETA approach involves working closely with market partners and other key stakeholders. Initiatives move through four stages of a life cycle that includes: 1) concept development; 2) program development; 3) market development; and 4) long-term monitoring and tracking. The majority of effort and resources are spent during the market development stage, which is the "implementation" stage that involves intensive market engagement. Before moving from one stage to the next, an initiative must be vetted and approved by a coordinating committee consisting of the DER and the utilities funding the ETA.

## Purpose of this plan

The Market Transformation Plan is the culmination of the program development stage, where extensive research and planning is done to prepare the initiative for market launch. The purpose of this plan is to summarize key contextual information, lay out the basic program logic and desired end state that informs our market strategy, and the present the fundamental market support activities necessary for success. This plan will then be the guide in developing specific activities each year during the market development phase. By being transparent in our objectives and strategies as much as possible, we hope to better facilitate stakeholder engagement, and alignment on strategy with key stakeholders, so we can together be coordinated and successful in achieving common goals. Supporting and informing this plan are

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<sup>1</sup> Minnesota Statutes § 216B.241 subd. 14 created the framework for the ETA program, which is funded by Xcel Energy, CenterPoint Energy, Minnesota Energy Resources, Minnesota Power, and Otter Tail Power.

the Market Characterization Report and the Energy Savings and Evaluation Plan (Appendices A and B).

## Summary of our approach

This section contains a brief summary of our approach, including our theory of how we expect to transform the market for high-performance windows (HPW).

Windows are the least efficient element of the building envelope, and as the nation moves to decarbonize its buildings, it will be imperative to improve this weak link. Windows make up only 8% of the typical home's building envelope area but account for 45% of envelope heat transfer.<sup>2</sup>

Improving homes' thermal envelope will have symbiotic effects on mechanical systems within homes. Tighter envelopes will allow for smaller HVAC and heat pump systems, which will maximize their effectiveness, lower operational costs, and minimize grid impacts of electrified heating loads. Because windows can last up to 45 years on average, decisions made today will have generational impacts.

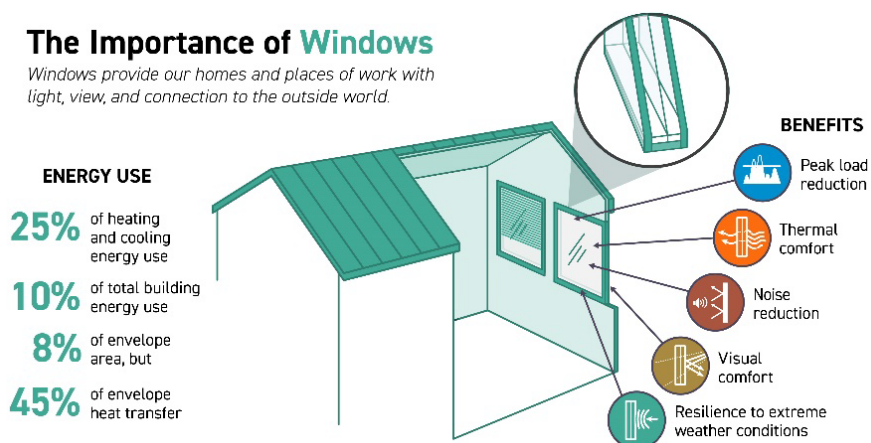
The window market has stalled over the past 25 years, accepting double-pane as the standard. Lack of awareness and complex market dynamics have slowed or halted the adoption of higher performing window products like triple-pane windows. Demand for these products is low, leaving manufacturers with little motivation to make the investments required to produce these products at scale.

There are several promising opportunities within the window market that could be leveraged to shift the market toward HPWs. Recent technology advances have made HPW design more flexible, efficient, and achievable. A recent update to the ENERGY STAR specification presents an excellent opportunity to market HPW through a channel that consumers are already familiar with. Research also shows that consumers value the energy efficiency of HPW. In addition, these products offer numerous non-energy benefits to consumers including noise reduction,

**Figure 1: The importance of windows**

### The Importance of Windows

*Windows provide our homes and places of work with light, view, and connection to the outside world.*



(Source: Illustration by Cristen Farley / Lawrence Berkely National Laboratory)

<sup>2</sup> U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, "Pathway to Zero Energy Windows" (April 2022). Available [here](#).

comfort, and additional health benefits. HPW can provide peak load reduction in addition to energy savings, a benefit that utilities value highly. Despite these opportunities, there are several barriers that must be overcome to shift the window market. Contractors typically do not promote HPW despite the suite of consumer benefits, and for consumers, the window purchasing process is complex, often resulting in efficiency taking a back seat to other window features. Manufacturers do not see the demand required to make process changes that would shift the market. Driving demand while maintaining engagement with manufacturers will be critical to increase the positive impact of decarbonization efforts and mitigate supply-side constraints.

Through ETA, we will articulate the value proposition for HPW and create tools and resources to increase education, awareness, and incentives for windows. We will also work with contractors to promote and sell HPW, which will drive demand. We will work to develop strong relationships with window manufacturers to share incentive opportunities and market insights and support product development efforts. By launching pilots and developing case studies, the value proposition of HPW can be developed and disseminated to builders and manufacturers.

Leveraging ENERGY STAR and getting HPW into more tax credits and utility programs will be essential to overcome the first cost barrier for homeowners, increase market adoption, and send a clear demand signal to manufacturers. This will motivate manufacturers to re-tool assembly lines for increased production of HPW, which will decrease costs and accelerate market adoption. Through successful strategic market support, this product will become the first choice for customers, which will drive demand, lower costs, and ultimately lead to incorporating HPW into the energy code.

## PRODUCT INFORMATION

### Product description

High-performance windows (HPW) include low U-factor (equivalent to high R-value) fenestration products used in single-family, multifamily, and some commercial buildings. These products improve the energy performance of a building by improving the envelope's thermal insulation, air leakage, and solar heat gain components to optimize HVAC performance. These products also offer an impressive array of non-energy benefits including improved comfort, noise reduction, and health benefits from reduced condensation.

Window technology has advanced over the years from the original fixed single-pane window to operable assemblies including multiple panes of glass and individual components that improve the product's thermal performance. ENERGY STAR is a strong brand in the window market and has been leveraged as a marketing tool for many years. Until recently, the ENERGY STAR certification for windows, doors, and skylights has been defined in the northern climate as a

window with a U-factor of  $\leq 0.27$ .<sup>3</sup> <sup>4</sup> Today, ENERGY STAR Version 6.0 windows make up a significant portion of the window market and typically take the shape of a double-pane window with a low-e coating.<sup>5</sup> Technology advances in recent years have created multiple pathways for manufacturers to achieve even higher-performing window products including high-performing low-e<sup>6</sup> double-pane windows and thin, hybrid, or standard triple-pane windows.

## Application types

High-performance windows (HPW) are most prominent in the residential sector and can be used in both replacement and new construction markets for single-family and multifamily homes. New construction has a high savings potential due to the volume of new construction, but replacement also presents significant market potential, due to the low efficiency of existing windows in residential homes and multifamily buildings. While multifamily buildings will be included in this effort, this product category is strictly residential. The commercial window market is distinct from the residential market, with regard to both supply chain dynamics and the product characteristics. The MN Energy Code also divides how new multifamily buildings are regulated based on building height. Buildings that are four stories and taller are governed by the commercial energy code, and buildings that are three stories and shorter are governed by the residential energy code. Some large multifamily buildings may use a combination of residential window products and commercial glazing, which is why the program will include multifamily as a potential target market segment.

Residential windows come in a wide variety of shapes, sizes, and operation (e.g., horizontal or vertical slider), and can be customized to meet a customer's needs. HPW are available in the same custom shapes and sizes as baseline code windows.

## Product specification

The high-performance window (HPW) initiative will align its efforts with the ENERGY STAR Version 7.0 prescriptive specification. As the initiative progresses, and the technology continues to advance, we expect the product specification for the HPW ETA initiative to tighten, entailing lower U-factor program targets. Below are the definitions of relevant terms and performance metrics, as outlined by ENERGY STAR and adopted by this initiative.

- **Insulating Glass Unit (IGU):** A preassembled unit, comprising lites of glass, which are sealed at the edges and separated by dehydrated space(s).

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<sup>3</sup> U-factor is the inverse of R-value, which is more commonly used in insulation products, whereas windows use U-factor. A U-factor of 0.27 is equivalent to an R-value of 3.7.

<sup>4</sup> ENERGY STAR, "Program Requirements for Residential Windows, Doors, and Skylights." Available [here](#). Version 6.0 for windows, doors, and skylights became effective in 2015 and was updated to [Version 7.0](#) in October, 2023.

<sup>5</sup> Low-e stands for low-emissivity and is used to describe windows with a coating that allows natural light to transmit through a window while deflecting UV and infrared light.

<sup>6</sup> These products typically have an additional room-side low-e coating and improved frame design, both of which improve performance over the typical ENERGY STAR Version 6.0 window.

- **Window:** An assembled unit consisting of a frame/sash component holding one or more pieces of glazing (typically an IGU) functioning to admit light and/or air into an enclosure and designed for a vertical installation in an external wall of a Residential Building. Includes Transoms.
- **U-Factor:** The heat transfer per time, per area, and per degree of temperature difference (Btu/h ft<sup>2</sup>·°F). The U-factor multiplied by the interior-exterior temperature difference and by the projected fenestration product area yields the total heat transfer through the fenestration product due to conduction, convection, and long-wave infrared radiation. The U-factor is also the inverse of the R-value, which is commonly used for insulation (e.g., an R-value of 5 is a U-factor of 1/5 or 0.20).
- **Solar Heat Gain Coefficient (SHGC):** The ratio of the solar heat gain entering the space through the fenestration product to the incident solar radiation. Higher SHGC values indicate more energy/heat radiated into interior spaces. Depending on window orientation, this can be a benefit during winter months, but result in higher cooling loads in summer months.
- **Air Leakage:** The volume of air flowing per unit time per unit area (cfm/ft<sup>2</sup>) through a fenestration system due to air pressure or temperature difference between the outdoor and indoor environment.

Physical Characteristics of high-performance window products include:

- Fixed or operable windows
- Can be installed or retrofitted in an existing wall with 2x4 framing construction
- Primary windows (excludes window attachments, storm windows, cellular shading, etc.)

The Northern zone specification of ENERGY STAR Version 7.0 for windows specifies a U-factor of  $\leq 0.22$  and a solar heat gain coefficient (SHGC) rating level of  $\geq 0.17$  or equivalent energy performance (Table 1). While the equivalent energy performance table allows for tradeoffs between U-factor and SHGC, higher SHGC products could have a negative impact on home energy performance and occupant comfort if not installed with orientation considerations. The ultimate goal of the HPW initiative is to shift the market toward lower U-factor products, rather than SHGC. Therefore, the HPW initiative will align with the prescriptive U-factor requirement of  $\leq 0.22$  defined by ENERGY STAR and omit the SHGC requirement and tradeoff options. ENERGY STAR Version 7.0 also specifies a window air leakage rating of  $\leq 0.3$  cfm/ft<sup>2</sup>. This set of specifications, excluding the equivalent energy performance table, will serve as the product definition for the HPW initiative.

**Figure 2: ENERGY STAR Version 7.0 energy efficiency requirements for windows**

Climate Zone	U-Factor <sup>1</sup>	SHGC <sup>2</sup>	
Northern	≤ 0.22	≥ 0.17	Prescriptive
High Performance Window Product Definition	= 0.23	≥ 0.35	Equivalent Energy Performance
	= 0.24		
	= 0.25		
	= 0.26		
	≤ 0.26	≥ 0.40	
North-Central	≤ 0.25	≤ 0.40	
South-Central	≤ 0.28	≤ 0.23	
Southern	≤ 0.32	≤ 0.23	

Air Leakage for windows ≤ 0.3 cfm/ft<sup>2</sup>  
<sup>1</sup> Btu/h ft<sup>2</sup>·°F  
<sup>2</sup> Solar Heat Gain Coefficient

## State of the product

High-performance windows (HPW) exist in the market today but face multiple market barriers, as outlined in the HPW Market Characterization Study (See Appendix A). There are several pathways to achieving HPW, but they typically leverage a combination of the following efficient window components:

- Room Side Low-e Coating
- Triple-Pane Insulated Glass Unit (IGU)
- Improved Spacers
- Thermally Improved Foam-Filled Frames
- Gas Fill

Detailed descriptions of these design components can be found in Appendix D.

These design components are utilized in the market today to varying degrees. A 2023 Study of [High-Performance Windows Incremental Manufacturing Cost](#) estimates that the incremental manufacturing cost to upgrade product lines from an ENERGY STAR Version 6.0 level of performance to the new ENERGY STAR Version 7.0 performance criteria is between \$1.80-\$2.10/SF with volume production.

Every major manufacturer has a product that meets the new ENERGY STAR Version 7.0 specification. However, these product lines make up a small portion of the window market. Because of this, demand needs to increase. Manufacturers have not yet seen a clear demand signal from the market indicating that consumers want HPW. As demand increases, manufacturers will have a clear business incentive for these products and will adjust their production practices to support manufacturing more high-performance products, driving down costs over time.



## Competitive landscape

There are several window products that could be considered competitive products to High-Performance Windows (HPW). These are products that currently dominate the market, may have a negative energy impact on consumers, or establish a perception of window products that negatively impacts HPW.

### *Code Minimum*

Code minimum windows in Minnesota are currently products with a U-factor of  $\leq 0.32$ .<sup>7</sup> These products are the go-to choice for many window replacements and new construction because of their competitive cost and availability. This presents competition for HPW products because of the significant incremental cost and lack of availability of HPW in the market today.

### *Double-pane Low-e*

Double-pane low-e windows have held a large market share in recent years, as the leading product type meeting the ENERGY STAR Version 6.0 specification. The high national market penetration of ENERGY STAR Version 6.0 windows was a key contributing factor to the specification update in 2023. Version 6.0 includes windows with a U-factor of  $\leq 0.27$  in the northern zone, which lands precisely between HPW and the code minimum. Double-pane low-e windows are readily available and typically cheaper than HPW. The features of this product are components that have been in the market for 15–25 years and are available from nearly all window manufacturers. These products present an obstacle to HPW adoption because of their cost, availability, and current reputation as the efficient window option.

### *High SHGC Windows*

High SHGC windows are an anticipated competitive product with the implementation of ENERGY STAR Version 7.0. The northern zone, which includes Minnesota, can achieve an ENERGY STAR Version 7.0 rating through a prescriptive path or a tradeoff approach that allows for higher U-factors with higher SHGC. Our market characterization work found that most manufacturers intend to meet ENERGY STAR Version 7.0 specifications through SHGC tradeoffs (See Appendix A). High SHGC windows can achieve energy savings if installed with orientation in mind but may have the opposite effect if installed with no consideration of orientation. This could increase cooling loads in the summer. Market characterization work revealed that most market actors, apart from architects, do not pay close attention to SHGC when selecting windows, and did not raise concerns with the SHGC tradeoff option built into the ENERGY STAR specification. Window products that meet ENERGY STAR through high SHGC

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<sup>7</sup> Buildings that fall under the commercial energy code (multifamily 4-stories and above) have different minimum code requirements.

Department of Labor and Industry, *Commercial Energy Code*. Available [here](#).

tradeoffs could lead to consumers paying higher energy bills, thus creating a negative perception of what they believed to be energy efficient window products.

## Luxury Windows

Luxury windows are available in the market today and are currently the most available avenue for purchasing HPW. The challenge is that luxury windows not only include the energy savings features that improve window performance – they also include luxury features like high-end hardware and expensive frame materials. This dramatically increases the price associated with these products, making them inaccessible to the average consumer. Products that only include efficiency features without the luxury bells and whistles are hard to find but are expected to be much more cost competitive with code windows. The current market perception of HPW products is that they are too expensive and this perception is fueled by the luxury window product class.

# MARKET DESCRIPTION

## Target market

The target market is the primary area of focus for the initiative. Table 1 below shows some general aspects of the target market for this technology including the sectors of focus for the ETA initiative, whether the initiative will focus on existing buildings, new construction or both, the current market size, and energy savings potential to provide a sense of opportunity scale.

**Table 1: High-Performance Window market summary**

<b>Sector (e.g., residential, commercial, industrial, etc.)</b>	Residential (single-family and multifamily)
<b>Existing buildings and/or new construction</b>	Existing buildings and new construction
<b>Current market size</b>	Total number of existing windows in Minnesota <sup>8</sup> : 27,050,670
<b>Technical savings potential</b>	480,000 MWh 12,000,000 Dth 13,000,000 total MMBTU

<sup>8</sup> U.S. Energy Information Administration, “2020 RECS Survey Data.” Available [here](#). Assumes 15 windows per home. The estimated number of detached and attached single-family homes and 2–4 unit apartments in Minnesota is 1,803,378 from EIA 2020 RECS data.

This initiative focuses on the residential market, which can generally be divided into two categories: new construction and replacement. Interviews with manufacturers completed through the market characterization study estimated a relatively even split between new construction and replacement window sales. Noting that this fluctuates with the economy and new construction industry. They currently estimate a 55/45 split, with more sales going to new construction. The high-performance window (HPW) initiative will include the new construction and replacement market, and therefore includes all window sales when projecting program impact.

We will also focus on incorporating HPW into affordable housing developments. These developments provide a great opportunity to showcase the benefits of HPW and ensure they are incorporated into affordable housing and not just market-rate construction.

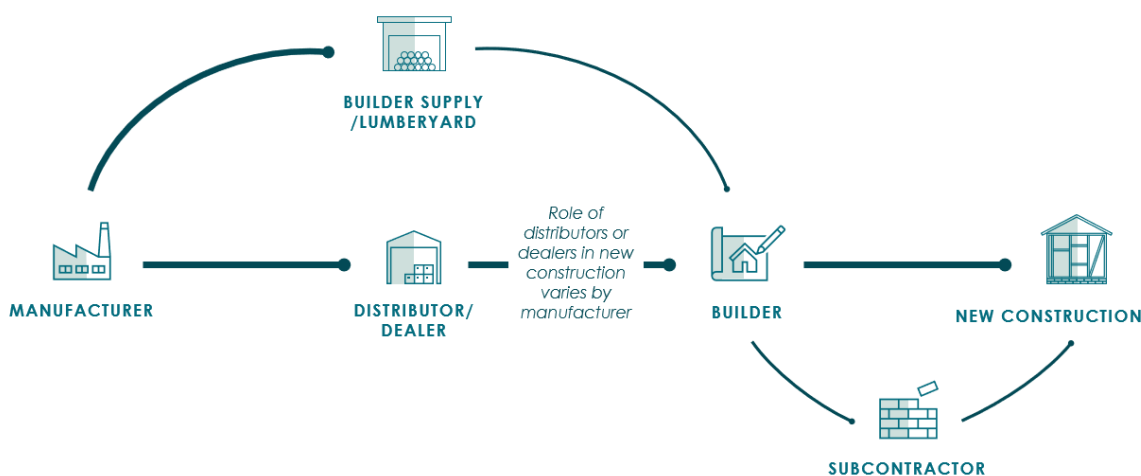
## Market dynamics and path to purchase

The High-Performance Window (HPW) Market Characterization found that window products are typically distributed from manufacturers to one of the following primary customers (See Appendix A):

- Distributors or dealers that sell to general contractors, unaffiliated installers, and (occasionally) homeowners.
- Big box retail, builder supply, and lumberyards that sell to general contractors, unaffiliated installers, and (occasionally) homeowners.
- Builders, who will often negotiate pricing for large developments or national contracts. Builders also place orders through local distributors or dealers.

This distribution network is complex and non-linear, as depicted in Figures 3 and 4 where bolder lines indicate the more common distribution channel.

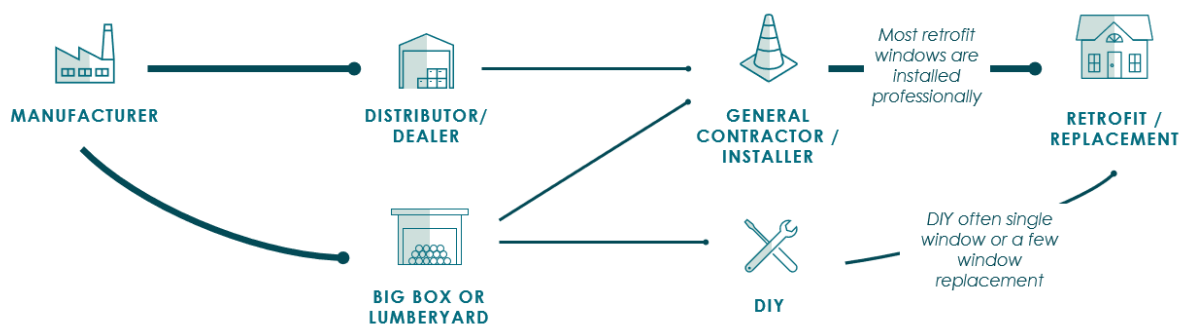
**Figure 3: Window supply chain: new construction**



The market dynamics of the new construction and replacement markets (as depicted in Figures 3 and 4, respectively), from an influence perspective, are quite different. Replacement projects

are often driven by homeowner needs related to comfort and aesthetic, new construction is primarily driven by cost. Because of this, distinct sales and marketing tactics are used for each market segment.

**Figure 4: Window supply chain: replacement/replacement**



The window replacement market has many channels, as depicted in Figure 4. The customer purchasing experience is complex in the replacement market, with several decision points aside from efficiency, all of which impact cost. Customers rely heavily on contractor opinions, as found in the NEEA Market Characterization Study, making this market actor a key influencer in the replacement market.<sup>9</sup>

Some key findings from the HPW Market Characterization Report related to window purchasing dynamics are listed below.

- Consumers are faced with multiple brands and product lines when they purchase windows.
- Double-pane low-e windows are considered standard practice in the replacement market.
- Homeowners are more likely to request or prioritize ENERGY STAR products in the replacement market than builders are in the new construction market.
- The new construction industry is driven primarily by cost and will often default to a code window.
- The window industry is a busy commodity market experiencing upward pressure on costs and labor.

The ENERGY STAR brand is prevalent in the window market. Window manufacturers have effectively leveraged this brand in their marketing tactics, and this is reflected in the market penetration of ENERGY STAR products, estimated nationally at 85%.<sup>10</sup> With the update to the ENERGY STAR specification for windows and doors, it is expected that this will be a key leverage point for HPW, especially in the replacement market. ENERGY STAR Version 7.0 goes into effect in October of 2023. This is the first time the window and door specification has been

<sup>9</sup> NEEA, "High-Performance Windows Characterization Study" (August 2022). Available [here](#).

<sup>10</sup> 2019 ENERGY STAR, "Market Share Report for Windows, Doors, and Skylights." Available [here](#).

updated since 2015. The new ENERGY STAR specification aligns with the product definition for HPW, opening the door for conversations with window manufacturers about their intent to leverage the ENERGY STAR brand with its new definition.

## PROGRAM LOGIC

### Long-term vision

The high-performance window (HPW) initiative will implement several strategic market activities with the programs desired end state in mind. If successful, manufacturers will shift production to prioritize HPW products, which will generate economies of scale and bring their cost down. HPW will become standard practice in new construction and will be the preferred option for existing building replacements. ENERGY STAR will continue to update its specifications to advance technology and maintain its status as the efficient product category. The desired end state of the HPW initiative is for MN Energy Code to require a U-factor of  $\leq 0.22$  for windows in new construction, and for market share of ENERGY STAR Version 8.0 to reach 50%. Our robust market support strategies will accelerate the market to achieve this ultimate end state.

### Market barriers and opportunities

There are several barriers that have been identified through our market characterization work that inhibit the adoption of high-performance windows (HPW). While these barriers exist, there are several opportunities that the market presents that will be instrumental in overcoming the obstacles this product faces.

#### *Barriers*

Numerous barriers exist in the market. For the purposes of this plan, we've narrowed down and identified five key barriers that will be considered in developing our market support strategies. These barriers were identified in the Market Characterization process and are as follows.

##### 1. Lack of awareness

The industry perception of triple-pane windows was established when the only triple-pane window options were thick, heavy products that utilize three panes at a standard thickness. These products were expensive and difficult to install due to their increased weight and frame size, so many builders and contractors avoided them and have maintained this negative perception even though new products have entered the market. Builders and contractors discourage homeowners from installing triple-pane windows due to their historical experiences and fear of being undercut on price by their competitors. Today, there is a lack of industry and consumer awareness of modern triple-pane technology, such as hybrid triples and thin triples, which address many of the preexisting concerns associated with triple-pane windows.

Our market characterization work found that there is significant confusion in the window market around ENERGY STAR, both in terms of market share and product definition (See Appendix A). This confusion makes it challenging to communicate efficient window features, further

obfuscating the purchasing conversation for homeowners and builders interested in evaluating efficient window options.

## 2. Lack of manufacturer business case for investing in HPW –

There are several manufacturing barriers associated with HPW. Thin glass, the center pane used in thin triples, cannot be tempered. This presents a barrier because life safety codes require tempered glass in specific applications. The process for manufacturing the Insulated Glass Units (IGU) that comprise an HPW is different than the process for manufacturing the standard double-pane low-e IGU that currently dominates the market. In addition, the national demand for double pane products is projected to be maintained due to life safety code requirements and lack of applicability to warmer climates. Due to these variations in process, and a projected maintained demand for double pane products, window and IGU manufacturers who invest in HPW production will need to be set up to produce both product lines at scale. For these reasons and a lack of demand from customers, manufacturers are hesitant to shift their production toward HPW.

## 3. The window industry is a busy commodity market experiencing upward pressure on costs and labor

Our market characterization work confirmed that the window market is complex, particularly in the replacement market (See Appendix A). There are several market dynamics that contribute to an ultimate increase in cost. A lack of window contractors and a surplus of window projects has resulted in contractors prioritizing big jobs that return a larger profit over smaller (1–6 window) projects. The lack of contractors and high demand has also led to high installation costs. The replacement market is also very marketing intensive, making customer acquisition costs a contributing factor to high installation bids. Window contractors compete with each other, often employing large discounts as a marketing tactic in an attempt to beat out a rival. Contractors also mention that they are hesitant to quote HPW for fear of being undercut by competitors.

## 4. Product selection is complex with many factors and features driving decisions

There are numerous features that customers consider when purchasing windows: frame material, latching mechanism, opening method, etc. Aesthetics and operability are typical motivations and priorities when it comes to window replacement. Each window feature impacts cost, and efficiency is often not considered a priority. When efficiency is discussed, a double pane low-e product is typically considered the efficient option. Customers must request high efficiency or triple pane products to receive a quote for HPW, and even then, can sometimes be dissuaded from this purchase for reasons mentioned in barrier #3.

## 5. New construction market is highly driven by first cost

As outlined in our market characterization study, the market dynamics within the replacement and new construction markets are complex but very different (See Appendix A). The new construction market is highly driven by first cost and will typically specify a code minimum window, unless the home is participating in an above-code program or energy efficiency is

prioritized (e.g., passive house construction). The significant overall cost of window packages and the incremental cost between a code minimum package and a HPW package make windows an easy target for keeping costs down and avoiding the perceived barriers outlined in barrier #1.

## *Opportunities*

There are significant opportunities that can be leveraged in the market to hasten technology adoption. Based on the Market Characterization research and team knowledge, we've identified the following key opportunities that have informed the development of our market support strategies.

### **1. US ENERGY STAR specification (Version 7.0)**

A new ENERGY STAR specification (Version 7.0) went into effect October 23, 2023. This specification creates an opportunity for national alignment on HPW product definition and can serve as a benchmark for utility programs and policies across the country. In addition, the updated specification has motivated manufacturers to consider product development and positioning of lower U-factor windows.

### **2. Technology innovations in window industry**

Numerous advances have been made in recent years that improve the efficiency of window products including the strength and reduced cost of thin glass, spacer performance, and window design in general. These advancements alleviate manufacturing concerns and improve the business case for HPW.

### **3. National/regional policies and programs can build HPW momentum**

In recent years, national and regional policies and programs that incentivize or mandate energy efficiency or decarbonization have increased. These include codes, tax credits, and above-code programs and policies. While many programs and policies are not specifying HPW, there is an opportunity to influence the requirements/specifications. Changing the requirements for these programs and policies can drive demand for envelope improvements, including window upgrades, which are a crucial component of energy efficiency and decarbonization.

### **4. Non-energy benefits for occupants**

Windows are unique for an energy efficiency measure in that they present a host of non-energy benefits to the consumer. Homeowners often replace windows for reasons other than energy efficiency, including comfort, noise reduction, and health. The health benefits of windows can be significant. Poor-performing windows can lead to condensation, particularly in cold climates like Minnesota. Condensation leads to mold, which can have serious impacts on the health of a home's occupants. In addition, windows provide a connection to the outdoors which has been



shown to have noteworthy effects on the mental health of residents.<sup>11</sup> These benefits can be leveraged to drive demand and awareness for HPW.

## Market support strategies

To leverage the opportunities that exist in the market and overcome known barriers, we've identified a comprehensive selection of key market support strategies, outlined in this section. The market support strategies are summarized in the table below, where the target audience(s) is highlighted for each. Several strategies will employ distinct tactics to reach multiple target audiences within the window market to influence the new construction and replacement markets.

As the team embarks on market support strategies, more intelligence about the market will be gained, the impact of the strategies will become better known and the market itself may evolve or shift. In order to optimize impact of the initiative, the team will adapt and potentially shift market support strategies over time. These changes will be carefully considered, documented and brought to the coordinating committee on an annual basis.

**Table 2: Market support strategies by target audience**

Market channel / Target Audience	Supply Chain		New Construction			Replacement		
	Manufacturers	Distributors	Builder Supply	Lumberyards	Builders/Architects	Contractors	Big Box Stores	Homeowners
<b>Market Support Strategy</b>								
Create case studies and pilots to demonstrate value proposition to market actors	x	x			x	x		x
Create, or co-create, marketing and educational materials and dissemination plans with market actors	x	x			x	x		x
Train and educate market actors	x	x			x	x		
Engage with national above-code programs and tax credits to ensure HPW specifications are included					x			x

<sup>11</sup> J.A. Veitch and A.D. Galasiu, "The Physiological and Psychological Effects of Windows, Daylight, and View at Home" (2012). Available [here](#).



Market channel / Target Audience	Supply Chain		New Construction			Replacement		
Engage utilities and local entities to incorporate HPW into program offerings, incentives, and policies		x	x	x	x	x	x	x
Participate in North American collaboration to build scale, share costs, influence codes, and amplify market demand signal	x				x			x
Contribute to advancement of ENERGY STAR specification to promote HPW							x	x
Engage with state energy code development to promote HPW	x				x			

1. Create case studies and pilots to demonstrate value proposition to market actors.

Demonstrating the value proposition of high-performance windows (HPW) will be critical to drive demand and transform the window market. The window purchasers or customers that are primarily responsible for driving demand are most often homeowners, builders, and multifamily developers. The program will deploy several tactics to reach each of these target audiences and demonstrate the value that HPW can provide to the end user.

To demonstrate the value proposition of HPW to customers, CEE will conduct several pilots. The pilots may take the form of one or all the following approaches.

- **Production builder pilot** – Engage with a local production builder to share cost, price, and product availability data, and facilitate a bulk purchase of HPW for a new development. This tactic may include a cost-share approach to offset the incremental cost to the builder.
- **Low-income single-family or multifamily developer pilot** – Engage with a low-income developer, such as Habitat for Humanity, to share cost, price, and product availability data, and facilitate a bulk purchase of HPW for a new development. This tactic may include a cost-share approach to offset the incremental cost to the developer.
- **Efficient builder pilot** – Engage builders participating in above-code programs for utilities and cities. CEE will share cost, price, and product availability data, and facilitate a bulk purchase of HPW for a new project. This tactic may include a cost-share approach to offset the incremental cost to the developer.

The pilots will be used to develop case studies to demonstrate the value proposition of HPW (see following strategy for additional detail on dissemination). In addition to pilots, CEE intends to engage in some or all the following activities to demonstrate the HPW value proposition to customers.

- **Parade of Homes** – CEE will work to have a new home with HPW highlighted on the Parade of Homes. Supporting marketing materials will be provided during the event to leverage the opportunity to reach homeowners and demonstrate the product quality.
- **Time of sale engagement** – CEE has experience working with local cities on time of sale energy disclosure because it has been identified that homeowners value energy efficiency upgrades at the time of purchase. The program will leverage this opportunity to educate realtors and inspectors on the value of HPW to disseminate to homeowners.
- **Events & conferences** – Program staff will attend conferences and events focused on efficient new construction in both the residential and multi-family categories to highlight the value proposition of HPW. Not only will this reach home builders and developers, but architects, distributors and manufacturers as well.

There are additional market actors that influence the purchasing decision of customers; window contractors, distributors, and architects are all influencers in the window decision making process. The primary tactic to demonstrate value proposition to contractors and distributors will be training, as described in the “train and educate market actors” activity. Architects will be targeted directly through 1:1 engagement or through events and conferences to distribute case studies developed from the pilots described above and additional marketing materials described below.

When customers and contractors understand the value proposition of HPW, they will begin to demand these products, and the supply chain will respond.

## 2. Create, or co-create, marketing and educational materials and dissemination plans with market actors

Marketing and education will be critical to disseminate the information gathered through pilots and demonstrations to manufacturers and market actors. The program team will work with utilities and national partners to develop a suite of marketing materials that can be used with a variety of audiences; homeowners, builders, contractors, distributors, manufacturers, architects and developers. The team will collaborate to co-create marketing and educational plans that can be leveraged by contractors, utilities, and manufacturers. These materials will be used for training and engagement.

CEE will leverage local pilots and demonstrations to develop case studies that highlight the benefits of HPW. The case studies may include interviews with builders pertaining to the product quality and installation experience. They may also include interviews with homeowners or occupants, discussing the product’s comfort and sound benefits. They may also include energy analysis, demonstrating the bill savings or HVAC system size reduction that resulted from the window upgrade. Builder focused case studies or one-pagers may also highlight above-code program opportunities that were achieved because of HPW.

In addition to case studies, the program will design and produce marketing materials that convey the following benefits related to HPW value proposition:

- **Decarbonization benefits** – HPW have the potential to reduce the HVAC system size, which can reduce system costs. For the same reasons, HPW can reduce peak loads for utilities by improving the building envelope.
- **ENERGY STAR Version 7.0** – The new ENERGY STAR specification has been updated to require a U-factor of  $\leq 0.22$  if following the prescriptive requirement.
- **Energy and bill savings** – HPW can significantly impact energy use and consequently energy bills. These products can last 35–45 years, so the impact is lasting. In addition, when coupled with HVAC replacement, reduced HVAC sizing can provide cost savings in both the new construction and replacement markets.
- **Window technology advancements** – In recent years, manufacturers have developed several methods to achieve HPW products: improved spacers, thin triples, hybrid triples, improved frame insulation etc.
- **Non-energy benefits** – HPW provide several non-energy benefits to customers: comfort, noise reduction, condensation/mold mitigation, etc.

We will work with a variety of market actors to create or co-create these materials and disseminate them through existing channels, including but not limited to contractor networks, utilities, city websites, and retailers. We will engage cities, nonprofits, and community-based organizations to ensure that our language and methods are accessible and that we reach low-income residents, and the industry serving those residents, through this engagement. This suite of marketing resources will disseminate the value proposition of windows across the market and address the current lack of awareness. Once the value proposition has been demonstrated and consumers are aware of the product, demand will increase and the market will begin to transform.

### 3. Train and educate market actors

Manufacturer sales trainings are a prime opportunity to influence how distributors and contractors talk about HPW. Many manufacturers administer product trainings to distributors and contractors that are focused on sales and marketing tactics. The program team will leverage the relationships we build with manufacturers to attend their trainings and highlight rebate opportunities and the value proposition of HPW to change how contractors and distributors think and talk about HPW.

We will also engage with manufacturers and distributors at industry focused conferences and events to share information and talk about the value proposition of HPW. We will partner with PAWS to broaden our reach and align messaging at local and national events.

In addition, CEE will work with Minnesota utilities to administer contractor trainings on HPW. These trainings will also focus on sales tactics and value proposition to teach trade allies how to promote HPW. The trade ally trainings may be associated with a specific utility program that will be highlighted during the training. CEE may also partner with PAWS to administer the trainings.

#### 4. Engage with national above-code programs and tax credits to ensure HPW specifications are included

National above-code programs influence decisions made in new construction. Many above-code programs have weak window requirements, often aligning with ENERGY STAR Version 6.0 or lower. We will engage with national program administrators to advocate for stronger window requirements in these programs. In addition to above-code programs, national affordable housing programs present an excellent opportunity to improve comfort for vulnerable populations. Some of the programs we intend to target are listed below.

- [Zero Energy Ready Homes \(ZERH\)](#)
- [ENERGY STAR Homes](#)
- [Weatherization Assistance Program](#)
- [Healthy Homes](#)
- [Green Communities](#)

Tax credits also influence both the new construction and replacement market. We will engage legislators to advocate for tax credit alignment with our HPW product definition. National alignment on how HPW are defined will increase awareness and clarity on product definition, as well as drive demand for HPW.

#### 5. Engage utilities and local entities to incorporate HPW into program offerings, incentives, and policies

Local programs, incentives, and policies also impact the purchasing decisions of builders and homeowners. We will engage with Minnesota utilities to expand program offerings and incentives for HPW, and partner on consumer awareness and promotional activities. These programs and incentives may take the form of program designs listed below.

- Midstream incentive structure to motivate distributors and retailers to stock and promote HPW.
- Customer incentive to mitigate the higher first cost, increase awareness, and ultimately motivate HPW product selection.
- Preferred contractor network that recognizes trusted contractors that promote HPW, develops a mechanism for price transparency, generates leads, and simplifies the purchasing process for consumers.

We will leverage these programs to reach low-income residents by engaging with home builders and multifamily developers that serve low-income populations. A distinct pilot or program design will be employed to ensure that low-income housing is constructed with efficient envelope components like HPW. These programs may employ a complementary or whole-home approach to optimize HVAC efficiency. Low-income and affordable housing programs will be engaged to include HPW specifications within these programs.

Utility programs may also be leveraged to develop and distribute consumer awareness materials highlighting the value proposition of HPW. In addition, local cities and jurisdictions often implement programs or policies to require or motivate new construction buildings to be

more energy efficient. We will engage the policy designers to ensure that HPW are included in the program/policy specifications, with a particular emphasis on including HPW specification in affordable housing programs. [Green Step Cities](#) is an example of a program that we intend to engage through ETA.

## 6. Participate in North American collaboration to build scale, share costs, influence codes, and amplify market demand signal

The partnership for advanced window solutions (PAWS) was developed to achieve these goals. The partnership engages with manufacturers, utilities, and other key stakeholders to disseminate information and conduct research to support the development of HPW products and initiatives across the country. Some key activities within this category are listed below.

- Develop code recommendation memos
- Co-create marketing plans and materials to align messaging
- Ensure alignment in utility and above-code programs
- Create nationwide presence at window-related conferences and events
- Collect and provide comments on spec. revision such as ENERGY STAR

## 7. Contribute to advancement of ENERGY STAR specification to promote HPW

The ENERGY STAR brand is very influential in the window market. PAWS was instrumental to develop ENERGY STAR Version 7.0. The next step will be partnering with ENERGY STAR to promote the brand and increase market penetration of products that meet the Version 7.0 specification. We will also work with EPA to develop advancements in the ENERGY STAR specification, with the goal of driving lower U-factor products and ideally removing SHGC tradeoffs. We will gather letters of support from our partners, supply market data, and demonstrate the need for a more advanced specification. This will further shift purchasing decisions, increase awareness of HPW, and send a clear market signal to manufacturers.

## 8. Engage with state energy code development to promote the inclusion of HPW

Energy codes are a key influencer in this market. The market support strategies executed through this initiative will create a base of demand and awareness that will support energy code updates and inform their development. Continuously advocating for advanced energy codes will signal the supply chain and contribute to the initiative's desired end state.

It is expected that as the residential energy code develops, performance path options such as the Energy Rating Index (ERI) Compliance Alternative will be adopted and used by a significant portion of the new construction market. This presents an opportunity and a barrier for energy code strategy as it relates to windows. The ERI compliance alternative allows builders to achieve energy code by outperforming prescriptive requirements in some areas, while underperforming in others, so long as the total ERI score meets the minimum requirement, aligning with a code-minimum home. This reduces the influence of a maximum prescriptive U-

factor requirement for windows, but presents an opportunity for builders to leverage window performance to meet energy code through ERI.

The program's key energy codes strategies are listed below.

- Advocate for lower maximum U-factors for fenestration within the residential and commercial energy code.
- Support efforts to include ERI compliance alternative and additional efficiency package in new code iterations.
- Monitor residential energy code update process and support efforts to accelerate adoption timelines.
- Provide technical support to ensure codes points and tradeoffs accurately represent the true energy savings associated with windows, including benefits from HVAC downsizing.
- Develop materials that highlight the opportunity for builders to use HPW to meet additional efficiency package requirements, total building performance pathway, and/or the ERI compliance alternative.

## PARTNERS AND ROLES

For this work, CEE plans to build partnerships with local and national stakeholders to establish a trusted voice in the market and influence change.

### Utility stakeholders

Minnesota utilities funding the Efficient Technology Accelerator (ETA) are key stakeholders that serve on the ETA Coordinating Committee. Utility representatives are also invited to serve on the Evaluation and Cost-Effectiveness Advisory Committee and the Market Strategy Advisory Committee. These utilities include:

- Xcel Energy
- Minnesota Power
- Otter Tail Power
- CenterPoint Energy
- Minnesota Energy Resources

Since this initiative technology is part of the natural gas and electric market, all listed utilities benefit from this initiative.

We are working with each of these utilities to develop cost-effectiveness calculations, provide savings and cost information, and launch window offerings in utility portfolios. Some specific activities that will involve our utility partners are listed below.

- Assist in designing incentive programs that align with HPW product definition. These may include a direct-to-customer rebate or a midstream or upstream rebate to motivate distributors and contractors to promote and sell HPW.
- Assist with developing pilots or campaigns that are focused on HPW adoption.

- Co-develop consumer awareness materials to distribute throughout utility contractor networks.
- Host or co-host contractor trainings on HPW value proposition and program opportunities.
- Enlist utilities to sign onto comments, such as for ENERGY STAR.
- Work with utilities and their program implementers to promote windows in their new construction programs and analyze data from these programs.

## PAWS

As discussed, achieving scale is crucial in the programs market transformation plan, and this scale extends beyond the Minnesota market. Therefore, coordinating with national partners is integral to the program’s plan. CEE has served on the steering committee for the Partnership for Advanced Window Solutions (PAWS) since 2021. We will continue this engagement and leverage the partnership to maintain national alignment, share resources, conduct research, and identify and address market barriers on a national scale.

The mission statement of PAWS is as follows:

*Through collaborative research and programs, PAWS will aggregate market demand, reduce product cost, quantify benefits, and accelerate the adoption of high-performance windows and window attachments. The collaborative will:*

- *Coordinate market transformation efforts across five initial priority areas/working groups.*
- *Share research, news, and updates across stakeholders, including progress on how individual partners are advancing PAWS priorities through their own ongoing efforts.*
- *Develop and maintain resources for partners to access in support of the PAWS mission and identify research gaps to move the advanced windows market forward.*

## Supply chain market actors

Supply chain actors will be a critical partner for the program. ETA is well positioned to develop a strong relationship with window supply chain market actors; several national window manufacturers are located in Minnesota or nearby. By assisting these local manufacturers with utility coordination, marketing, and technical support, ETA will not only accelerate the adoption of HPW, but also improve the Minnesota economy.

## NEEA

CEE has worked closely with NEEA on this initiative since CEE’s involvement with PAWS began in 2021. Monthly collaborative meetings occur between the ETA HPW team and the NEEA HPW where the teams share strategy regarding market data, strategic interventions, product definition, and manufacturer engagement. ETA will continue to leverage this relationship to maintain alignment, share strategies, and broaden the program’s impact.



# SAVINGS POTENTIAL

There is significant savings potential with this initiative. Technical potential represents the total achievable savings if we were able to influence the market to a maximum effect. The estimated total technical potential for the high-performance window (HPW) initiative is 470,000 MWh and Million Dth. This estimate is based on modeling completed by Lawrence Berkeley National Laboratory (LBNL). The modeling completed by LBNL estimated the energy use of a model home with code minimum windows (U-0.32), and ENERGY STAR Version 7.0 (U-0.22) windows. This energy use was then compared to establish savings for HPW over a code baseline (U-0.32).

**Table 3: Modeled energy savings per 3'x5' window for ENERGY STAR Version 7.0 window replacement over energy code baseline for four Minnesota cities**

HVAC Scenario	Electric forced-air furnace		Gas Heating, no AC		Gas Heating, with AC		Heat Pump	
	Electricity (kWh)	Gas (Therm)	Electricity (kWh)	Gas (Therm)	Electricity (kWh)	Gas (Therm)	Electricity (kWh)	Gas (Therm)
Minneapolis, MN	83	0.0	2	3.4	0	3.6	69	0.0
Rochester, MN	91	0.0	3	3.7	2	3.7	77	0.0
Duluth, MN	104	0.0	3	4.2	1	4.2	88	0.0
Bemidji, MN	86	0.0	3	4.4	2	4.3	87	0.0

This modeling analysis was completed by Lawrence Berkeley National Laboratory (LBNL) using EnergyPlus modeling software. This analysis was completed with support from the Partnership for Advanced Window Solutions (PAWS - paws.energy).

To estimate statewide technical potential for this initiative, the modeled per-window energy savings listed in Table 3 were normalized based on population, climate, and statewide HVAC system type distribution. A detailed description of the calculation methods can be found in Appendix C.

# RISK MITIGATION PLAN

Risks are inherent to any project. However, we have identified key anticipated risks and developed mitigation strategies. These are described in Table 4 below.

**Table 4: HPW risk mitigation matrix**



"IF" this happens	"THEN" this will occur (impact)	Probability (H/M/L)	Impact (H/M/L)	Risk response: (Accept, avoid, mitigate, transfer)	Response plan
IF high SHGC windows are promoted as HPW and are installed in non-optimal scenarios	THEN the market may develop a negative association and bias against HPW	M	H	Mitigate	Define product spec. and promote utility programs based on prescriptive ESV7 pathway without SHGC tradeoffs
IF new programs, tax credits, and policies neglect HPW	THEN the market won't recognize HPW as a key energy efficiency upgrade and may install lower performing window products, prioritize other EE upgrades, or miss an opportunity to reduce HVAC load during heat pump upgrades by improving envelope performance	M	M	Avoid	The program will engage program administrators, policy writers and national stakeholders to incorporate HPW in applicable programs
IF the demand for HPW is not large enough to justify adjustments to manufacturing practices	THEN the program will not see the necessary price declines needed for rapid adoption of HPWs	L	H	Mitigate	Help reduce their investment risk by pooling resources with PAWS to create a big enough carrot for manufacturers to overcome the initial hurdle of changing over or adding triple-pane production lines
IF production builders do not utilize HPW	THEN the program will not have a strong enough early demand signal for manufacturers	L	M	Mitigate	Provide incentives to builders to try HPWs and create marketing materials and case studies

"IF" this happens	"THEN" this will occur (impact)	Probability (H/M/L)	Impact (H/M/L)	Risk response: (Accept, avoid, mitigate, transfer)	Response plan
					that show demand and reduce barriers
IF the program is unable to purchase or collect window sales data	THEN the program will not be able to measure impacts and savings	L	H	Mitigate	Coordinate with NEEA to pool resources to acquire good sales data and outline a diverse approach to acquire data from multiple sources
IF utilities do not launch window programs and a window measure is not incorporated into the MN Technical Reference Manual (TRM)	THEN consumers will have a harder time justifying incremental cost and differentiating product and consumer awareness will not improve based on utility marketing	L	M	Mitigate	Work with utilities on incentive program strategies and incorporate HPW into the MN TRM
IF manufacturers are not receptive to program support on market engagement	THEN manufacturers will not promote HPW to customers and prioritize their production	L	M	Mitigate	Be intentional about engaging manufacturers to ensure a trusted relationship develops and gain an understanding of their opportunities, barriers, and market drivers

# TRANSITION PLAN

Once the market development strategies have been deployed for a number of years and achieve their desired impact, the team will monitor market share, market progress indicators, and the code and standards landscape to determine the right time for the program to pull back market development activities. This will include transitioning critical functions to the market and a

move into the Long-Term Monitoring and Tracking (LTMT) phase where sales will be tracked and analyzed to measure savings, but market support activities are discontinued. Determining readiness for transition from market development, a resource intensive phase, to LTMT, a resource light phase, will require careful monitoring and assessment to determine optimal timing. The ETA coordinating committee will review and approve the transition to LTMT.

The high-performance window (HPW) team will monitor the progress of the initiative and re-evaluate strategic interventions as necessary. Interventions will be adjusted to ensure sustained acceleration of market adoption, leading to the ultimate impact: by 2040, the market share of ENERGY STAR Version 8.0 windows will be 50% or higher and code will require windows with a  $\leq 0.22$  U-factor.

We will exit the market when it is evident that accelerated market adoption can be sustained without active intervention. At this time, the initiative will be transitioned into the Long-Term Monitoring and Tracking phase, during which the team will minimally engage with the market but will track HPW market penetration and evaluate re-engaging with the market if adoption declines or becomes stagnant.

# APPENDIX A: MARKET CHARACTERIZATION

See HPW Market Characterization Report

# APPENDIX B: ENERGY SAVINGS AND MARKET EVALUATION

See HPW Energy Savings and Market Evaluation Plan

## APPENDIX C: HPW DESIGN COMPONENTS

**Room Side Low-e Coating.** Historically, higher-performing window products use a low-emissivity (or low-e) coating on surface 2 (inside surface of exterior glass pane) to block ultraviolet and infrared light but allow visible light to pass through. Newer HPW use similar coatings on multiple surfaces of the window glazing, including the interior. This approach typically reduces the U-factor of a window by 0.04 if the coating is applied to the fourth surface (room side) of a double-pane window. This feature is common today and can easily be adapted to improve the efficiency of new window products.

**Triple-Pane Insulated Glass Unit (IGU).** Triple glazing has been around for a while, but previously required a redesign of the standard double-pane window sash because of the heavier, wider glass assembly. Consequently, builders and manufacturers have avoided these products. Recent technology advances have allowed manufacturers to develop triple-pane products that are thinner and lighter. There are two main types of modern triple-pane products, hybrid triples, which utilize three panes of equal thickness that are all thinner than the panes of a standard double-pane, and thin triples, which utilize two thicker (comparable to double-pane) layers of glass plus a thin layer of glass between them. There is a negative market perception of traditional triple-pane products, so contractors are unlikely to recommend these products to customers.<sup>12</sup> This negative perception is largely due to the product weight and historic cost of traditional triples and most window manufacturers are currently not set up to produce hybrid or thin-triple products at scale.

**Improved Spacers.** Window spacers are the strips of plastic, metal, or foam that separate glass panes in a window. Traditional windows may have metal spacers with poor insulative properties. Even though the spacers are a small part of the overall window assembly, the energy impacts of these components can be significant due to their ability to prevent air and gas leakage, moisture penetration, and thermal bridging. Improved non-metal spacer designs have entered the market in recent years and are designed to improve the overall efficiency of window products by preventing air leakage and heat loss at a window's perimeter, these spacers are typically known as warm edge spacers.

**Thermally Improved Foam-Filled Frames.** Some manufacturers have found success by insulating their window products' frame with either spray foam or push-in foam. Like improved spacers, this approach improves the product's thermal efficiency by reducing heat loss around the window perimeter.

**Gas Fill.** Gas-filled windows provide an additional layer of insulation and increase windows' overall efficiency. Manufacturers most often use krypton and argon for gas fills. Argon is a relatively inexpensive gas fill option commonly used in efficient window technologies. Krypton

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<sup>12</sup> NEEA found that the supply chain is unlikely to recommend triple-pane products. NEEA, "High-Performance Windows Market Characterization Study" (August 2022), Figures 2–3. Available [here](#).

is a better insulator, but its cost has been volatile in recent years, making it a less attractive option for manufacturers. It will be critical to assist manufacturers in determining ways to produce HPW products without the use of Krypton, given its price volatility. The aforementioned features, when combined, can produce an HPW meeting ENERGY STAR Version 7.0 specifications with Argon gas fill.